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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Serial No. 10/650,210
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Filed August 28, 2001

Goro Tamai
William L. Aldrich III

Group 3744

CLIMATE COOLING CONTROL SYSTEMS
AND METHODS FOR HYBRID VEHICLES

Examiner William E. Tapolcai

AFFIDAVIT UNDER 37 CFR 1.131

Commissioner for Patents
PO Box 1450
Alexandria VA 22313-1450

Goro Tamai, being duly sworn, deposes and says:

William L. Aldrich III, being duly sworn, deposes and says:

1. I am an inventor of claims 1-20 of the patent application identified above and an inventor of the subject matter described and claimed therein.

2. Prior to June 11, 2002 having earlier conceived of the idea for the claimed invention "Climate Cooling Control Systems And Methods For Hybrid Vehicles," and with due diligence, I reduced the invention in the United States as evidenced by the attached invention disclosure form and documentation. The dates have been redacted from the invention disclosure and documentation.

3. That all statements made above of my own knowledge are true, that all statements made above on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under title 18 United States Code, Section 1001 and may jeopardize the validity of the application or any patent issuing thereon.

Goro Tamai

William L. Aldrich III

Subscribed and sworn to before me this 26TH day of OCTOBER, 2004.

Stephen R. Kornelium

Notary Public

General Motors Corporation
Legal Staff
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STEPHEN R. KORNELIUM
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MY COMMISSION EXPIRES Apr 4, 2007

Attachment

CONFIDENTIAL AND PRIVILEGED

GM **GENERAL MOTORS CORPORATION**

RECEIVED

BY: S.R. Kamblu

File No. GP-302391

DTE 2002053

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RECORD OF INVENTION

This Record of Invention must be completed with sufficient detail so that your invention can be understood and evaluated by both your engineering management and by a GM Legal Staff patent attorney. Novelty and competitive significance of your invention will be evaluated based on the information you provide.

Invention Title: Hybrid Climate-Control System for a Hybrid Vehicle

Inventor #1

Name: Goro (First Name) ___ (Middle Initial) Tamai (Last Name) Citizen of: Japan

Social Security No. 134-70-2665 GM Employee: ☐ Yes ☐ No ☒ Salary ☐ Hourly ☐ Contract

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GM Address: PO Box 7025, Troy MI, 48007-7025 Mail Code: 480-990-071 FAX Number: (8)-258-7157 (Centrex Number)

Non-GM Employer: ___ Phone No. ___ ((Area Code) + Number)

Non-GM Employer Address: ___ (Street) ___ (City and State) ___ (Zip Code)

Inventor #2*

Name: William (First Name) L (Middle Initial) Aldrich III (Last Name) Citizen of: USA

Social Security No. 365-64-8331 GM Employee: ☒ Yes ☐ No ☒ Salary ☐ Hourly ☐ Contract

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Non-GM Employer: ___ Phone No. ___ ((Area Code) + Number)

RECEIVED GENERAL MOTORS CORPORATION

Non-GM Employer Address: ___ (Street) ___ (City and State) ___ (Zip Code)

* If there are more than two (2) inventors for this invention use the template at the end of this form.

LEGAL STAFF

Answer questions 1 - 8, completing all of them to the best of your knowledge.

1. This invention was first thought of on: [illegible]

2. This invention has been or is expected to be disclosed outside GM on: TBD

3. This invention has been used or is committed to be used in production on: TBD

4. This invention has been offered for sale outside GM on: N/A

5. Was this invention made while working on a Government Contract? ☐ Yes ☒ No

   If yes, identify the government Contract No. ______

6. Identify the product or process in which the invention is incorporated: Hybrid Vehicles

7. List all individuals who can provide information about the making of the invention. This list may include individuals who made the first sketch, description, or tests and individuals who are familiar with the facts relating to the making of the invention.
   Tony Hoang, Tony Corsetti, David G. Evans

8. Each inventor has a legal duty to disclose all information known that is material to patentability of this invention. Such information includes the relevant prior art, which may be in the form of current or past products, equipment, processes, materials, patents, publications, advertisements, displays, and unpublished developments and proposals—whether originated by you, others in GM, competitors, suppliers, customers or others. Such information also includes disclosure of this invention outside GM, sales and offers of products using this invention, use of this invention in production and disputes about who should be considered as an inventor of this invention. To comply with the duty to disclose, list here and attach a copy of all such information, to the extent known.
   N/A

Answer question 9 thoroughly.

9. Describe the invention in sufficient detail so that its nature, operation and usefulness can be understood. (Attach drawings, diagrams and further description, when necessary. Additional guidelines are listed below.)

Please see attached document, "Hybrid Climate Control Patent App-3.doc."

Mechanical and Electrical Devices: Include illustrations assigning reference numbers to the main elements and refer to the reference numbers in a description that explains how the main elements are connected or related and how they operate.

Electrical Circuits and Controls: Include circuit diagrams and a functional description.

Computer Software and Manufacturing or Business Processes: Include a flowchart or other step-by step overview.

Chemical Inventions: Identify all essential materials used, and alternatives therefor, in chemical terms – not tradenames. Identify and quantify all significant variables (e.g. temperature, pressure, concentration, pH etc.) of the process or material specifying operating ranges and the preferred example. Discuss the significance of each variable. Provide a recipe for at least one working example of the invention.

Answer the following questions if helpful in describing this Invention

10. What benefits will be realized by using this invention?

Hybrid powertrains gain a substantial portion of its fuel economy benefit from Engine-Stop-Start (ESS) functions. However, if the Air Conditioning system is on, in many cases, the engine is not turned off when the vehicle comes to a stop.

With the Hybrid Climate Control System (HCCS), the A/C compressor can be mechanized such that it can be rotated even when the engine is stopped. In order to keep the system economical and technically practical, the initial cool down of the cabin is executed with the compressor powered by the engine. For A/C "maintanence" a relatively low-power non-engine-powered drive (e.g. electric) mounted to the compressor is used. A clutch (e.g. freewheel) prevents backdrive ot the motor during conventional A/C operation, thus reducing drag (Patent Application "Parallel-Drive Air-Conditioner Compressor", April '02)..

Once steady cabin temperature is reached, the HCCS allows fuel saving ESS functions while providing passenger comfort.

11. What is the state of development of this invention?

Concept development, supplier discussions for prototype hardware.

12. To the extent known, what alternatives exist for accomplishing substantially the same result as this invention?

Toyota has introduced a hybrid system in which the crankshaft pulley can be declutched from the crankshaft, allowing the motor-generator (main hybrid motor) to turn the entire accessory drive system independent of the engine. The Toyota system powers the hydraulic power steering, water pump, and the A/C compressor (in addition to rotating an array of idler pulleys). The HCCS proposed is different in that only the A/C compressor is electrically rotated, independent of the belt drive, and the failure modes and steady-running energy consumption of a crankshaft clutch are avoided.

There have been other systems proposed that use a host of clutches and gears, and a dedicated belt drive system to power the compressor through the transmission.

Purely electrically driven compressors have been proposed, which would require a high power (numerous kW) motor and a costly power-inverter system.

Mechanically, a similar compressor with an electric motor attached to the tail of the unit has been shown, but without a clutch. Thus the motor would end up being backdriven during conventional A/C operation, creating unnecessary drag (Patent Application "Parallel-Drive Air-Conditioner Compressor", April '02)..

13. Describe the background of the invention. This description may include the state of the prior art and may identify deficiencies in the prior art that are overcome by this invention.

Hybrid powertrains gain a substantial portion of its fuel economy benefit from Engine-Stop-Start (ESS) functions. However, if the Air Conditioning system is on, in many cases, the engine is not turned off when the vehicle comes to a stop.

With the Hybrid Climate Control System (HCCS), the A/C compressor can be mechanized such that it can be rotated even when the engine is stopped. In order to keep the system economical and technically practical, the initial cool down of the cabin is executed with the compressor powered by the engine. For A/C "maintanence" a relatively low-power alternatively energized drive (e.g. electric) mounted to the compressor is used.

I hereby assign this invention to General Motors Corporation and authorize General Motors Corporation to file an application on my behalf.

	Goro Tamai	
INVENTOR – SIGNATURE	**(ALSO, PRINT NAME)**	**DATE**
	William L. Aldrich III	
INVENTOR – SIGNATURE	**(ALSO, PRINT NAME)**	**DATE**
INVENTOR – SIGNATURE	**(ALSO, PRINT NAME)**	**DATE**

This invention was reviewed and understood by me:

	Anthony J. Corsetti	
1st WITNESS – SIGNATURE	**(ALSO PRINT NAME)**	**DATE**
	Tony Hoang	
2nd WITNESS – SIGNATURE	**(ALSO, PRINT NAME)**	**DATE**

Goro Tamai
William L. Aldrich III

Hybrid Climate Control System (HCCS) for Hybrid Vehicle

In some hybrid or mild-hybrid powertrain systems, an electric motor-generator (MoGen) system replaces the conventional starter motor and alternator. When the vehicle is decelerating or is stopped, the fuel flow to the engine is shut off to improve fuel economy. The MoGen system is implemented to enable this fuel-cutoff feature while minimally affecting driveability. In a mild-hybrid powertrain with an automatic transmission, upon brake-pedal release from a stop, the MoGen system spins up the engine, and creeps the vehicle forward, similarly to a conventional vehicle with an automatic transmission. The engine combustion can be commenced after some time, or if the accelerator pedal is depressed. When the engine is running, the MoGen acts as a generator to supply the vehicle's electrical power requirements, as well as recharging the battery pack. When the engine is off, the vehicle's electrical loads (fans, radio, etc.) are supported by the battery system and a DCDC converter. The MoGen also acts as a motor during implementation of the MAP Trap Control (Patent Application, "Hybrid MAP Trap Control System," April '02), and the hybrid functions discussed below. For a hybrid powertrain with a step transmission (e.g. 4-speed automatic), the MoGen can act as a motor during fuel-off deceleration downshifts to synchronize the engine and transmission speeds (Patent Form H-205736). Though "Hybrid Powertrains" often refer to hybrid-electric powertrains, other forms of hybridization (e.g. hydraulic) can be considered for this application.

In some hybrid powertrains, when the vehicle comes to a stop with the engine not rotating, the air-conditioning (A/C) compressor is also not rotating. Though some cool air may still be blown, the air can become warmer than desired, and stale (odorous) in less than a minute. Various solutions to this problem have been proposed that include: (a) independent electric A/C systems with high-power electronics to energize the compressor, or (b) using the hybrid drive motor to clutch in/out to rotate the existing compressor. The demerits of these systems include high cost power electronics and electric drive motors, complicated clutch/drive mechanisms whose failure modes could implicate base-engine hardware functions, and additional accessory drive components.

In a hybrid vehicle, a substantial portion of the fuel economy improvement is gained from the Engine Stop Start (ESS) functions. Thus, it is important to preserve as much of the ESS capabilities as possible, regardless of the environmental conditions and desired driver comfort level.

In this application, the hybrid powertrain hardware architecture can be such that the A/C compressor can be operated independently of the internal-combustion engine and the traditional front-of-engine accessory drive system. One embodiment of this concept is an A/C compressor that has a conventional pulley/clutch assembly at the front of the unit, but has an electric motor placed inside of, or at the tail of the unit. Thus, with the A/C clutch disengaged (with or without the engine spinning), the compressor can be motored electrically. Additionally, if the engine is driving the compressor, a clutch (e.g. one-way clutch/freewheel, or centrifugal) can be positioned between the compressor and the motor such that the electric motor will not be backdriven by the compressor, thus reducing friction losses (Patent Application "Parallel-Drive Air-Conditioner Compressor," April '02). For the remainder of this document, and electric drive in the Hybrid Climate Control System (HCCS) will be assumed, though other forms (e.g. hydraulic) of compressor energizing can be considered.

To minimize cost, mass, part-count, and added complexity, the HCCS hardware could be minimal in electrical power (e.g. fraction of full compressor power, or several hundred Watts), single speed, single load, single discrete on-off command with a diagnostics system (e.g. motor temperature). The A/C compressor motor system voltage can be at the conventional 12V, or at a higher hybrid-system voltage (e.g. 36V, 120V, etc.).

The goal of this control system is to first let the internal-combustion engine (ICE) power the A/C system to draw down the cabin temperature, then, once the A/C system is in a cabin "climate maintenance" mode, the ESS functions and the HCCS can be enabled.

In a vehicle *without* an Automatic Climate Control System (Auto-CCS), the driver is solely responsible for setting the fan speed, temperature setting, and whether the A/C compressor is activated via A/C-clutch engagement (though clutch disengagement is sometimes automatically executed by the HVAC or powertrain control system).

In many engine control systems, the outside ambient air temperature (T_amb) is estimated from the Intake-Air-Temperature (IAT) sensor readings. Based on this T_amb and the A/C system diagnostic data available (e.g. compressor high-side pressure), a critical A/C-on time for Engine-Stop-Start (ESS) functions is determined. This time, t_ac-ss, is calibrated to be longer for higher calculated heat-rejection load. The T_amb is monitored at the time the A/C compressor is commanded on, and sampled for a given time, t_aat. The t_aat must be long enough such that large temperature differences between the key-up location (e.g. garage) and the outside street are not confused.

Other parameters that can elongate the t_ac-ss time include: low battery state-of-charge (SOC), high temperatures in the hybrid system (motor, power electronics, battery, etc.), rear-window defogger on-status, or hybrid system fault codes. In the case of extreme (high or low) T_amb or extreme humidity (modeled or measured), the ESS functions and/or the HCCS can be suspended.

Depending on the hybrid powertrain architecture, the engine is stopped (0 rpm) only when the vehicle is stopped (0 mph). In other cases, the engine can be stopped while the vehicle is rolling. In either case, with a conventional A/C drive system run through the front accessory drive, the stopping of the engine equates to the stopping of the A/C compressor function. Thus, in the HCCS, the electric operation of the compressor is triggered by a critical engine speed (ERPM). For example, if the critical ERPM is 400 rpm, as the engine is stopping from 1000 rpm and falls through 400 rpm, the electric A/C motor is activated to control the compressor speed to the desired value. Any non-zero critical ERPM can utilize the compressor rotational momentum previously supplied by combustion power, reducing the electric power spike, characteristic of a starting motor. Also, powering the compressor so that it continuously turns without coming to a stop, reduces the change in vehicle noise, which may improve customer pleaseability.

In the case that the A/C system is turned on during an engine-stop condition, the HCCS can start electrically driving the compressor, or signal an engine restart. Under normal HCCS operation, to disengage the HCCS, the engine restart command must be issued. To reduce the battery draw during the short high-power engine start, the compressor motoring power is disabled at the onset of the hybrid motor (engine-cranking motor) power draw. If the Parallel-Drive A/C Compressor is not electrically driven, the compressor operation can be continued through the engine restart.

If there are diagnostic codes such as low-battery, the A/C operation will be momentarily suspended to give highest power priority to engine restarting. Similarly, if the A/C high-side pressure is approaching a higher-than-desirable value, the HVAC fan is turned on (if battery SOC is sufficient) or the engine is restarted.

If the A/C load is very low, the ESS functions can be enabled without the HCCS operations. In this case, the engine would stop, and the A/C compressor would also stop. This is most applicable in a vehicle with automatic climate control, in a condition when the compressor was not energized.

If the HCCS motor performance is compromised (e.g. A/C compressor motor is hot), but the rest of the hybrid/powertrain/vehicle systems are fully functional, *and* the T_amb, blower settings (if available) and humidity (if available modeled, measured, or inferred from defogger status/history) are within a calibrated range, the ESS functions can still be enabled. In this case, the A/C compressor motor would not be energized, thus after a calculated engine-stop time or a higher A/C request from the driver, the engine would be restarted.

An example of the HCCS system without an Auto-CCS can be envisioned as follows. The vehicle is keyed-up in a cool garage on a hot summer day. Thirty seconds later, the vehicle is driven outside with the A/C on. Over the following few minutes, the A/C system controller (programmed into the engine control module (ECM)) calculates the T_amb. Based on this T_amb, and the diagnostics of the powertrain, hybrid system, and vehicle systems, the t_ac-ss time is calculated to be 10.5 minutes. After 10.5 minutes of stop-and-go driving, the ESS functions are enabled. At the following stop light, the engine-stop command is processed, and when the ERPM passes below the critical value of 400 rpm, the compressor is electrically driven to maintain the HVAC air outlet temperature. When the driver commands to resume driving, the engine restart command is given, and the HCCS disengages at the onset of power draw from the engine-cranking motor system.

The mechanical layout of the HCCS is shown schematically in Figure 1. The belt-driven motor-generator can be interchanged with a flywheel motor-generator (mounted to the crankshaft between the engine and the transmission). The control system described above is schematically represented in Figure 2a,b.

For a vehicle with an Automatic Climate Control System, the above functions can be automatically coordinated in conjunction with the numerous temperature sensors and blower settings.

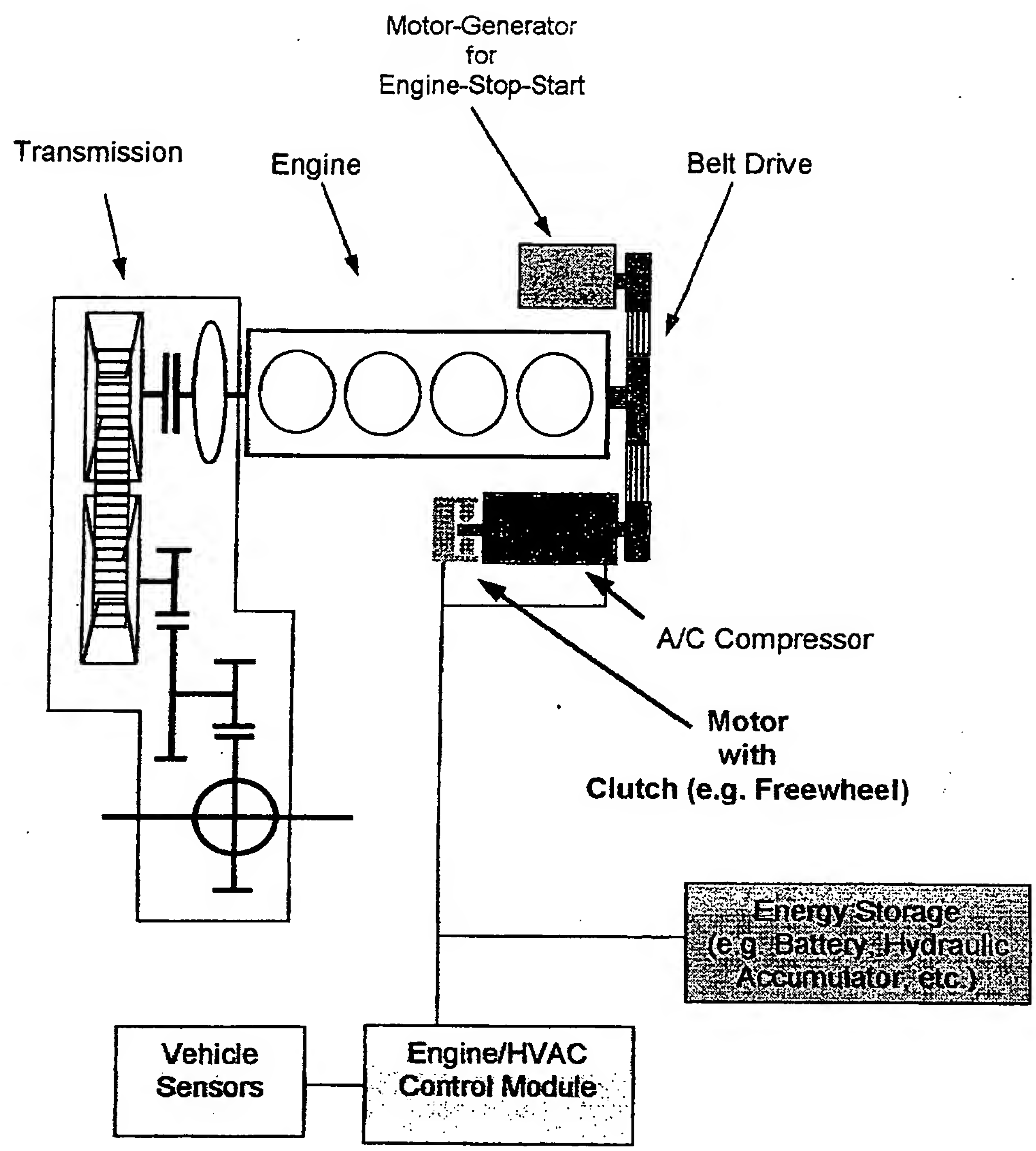

Figure 1: Simplified mechanical schematic of the Hybrid Climate Control System (HCCS).
(From Patent Application "Parallel-Drive Air-Conditioner Compressor",

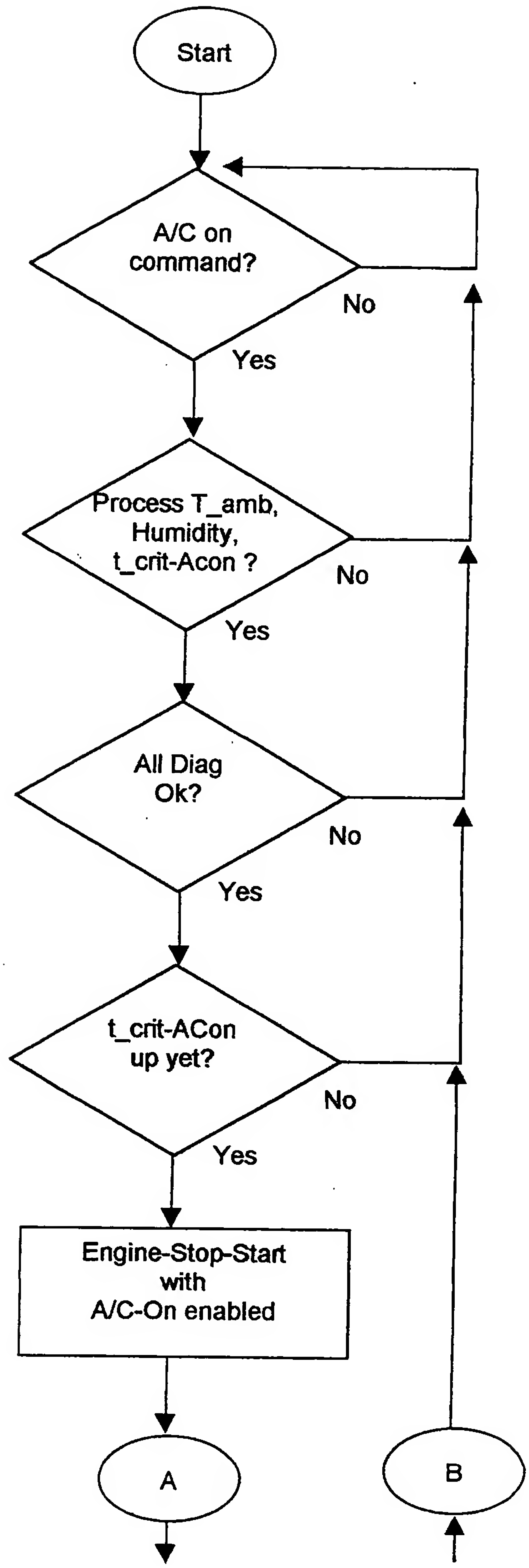

Figure 2a: Simplified schematic of the Hybrid Climate Control System (HCCS); Portion 1 of 2.

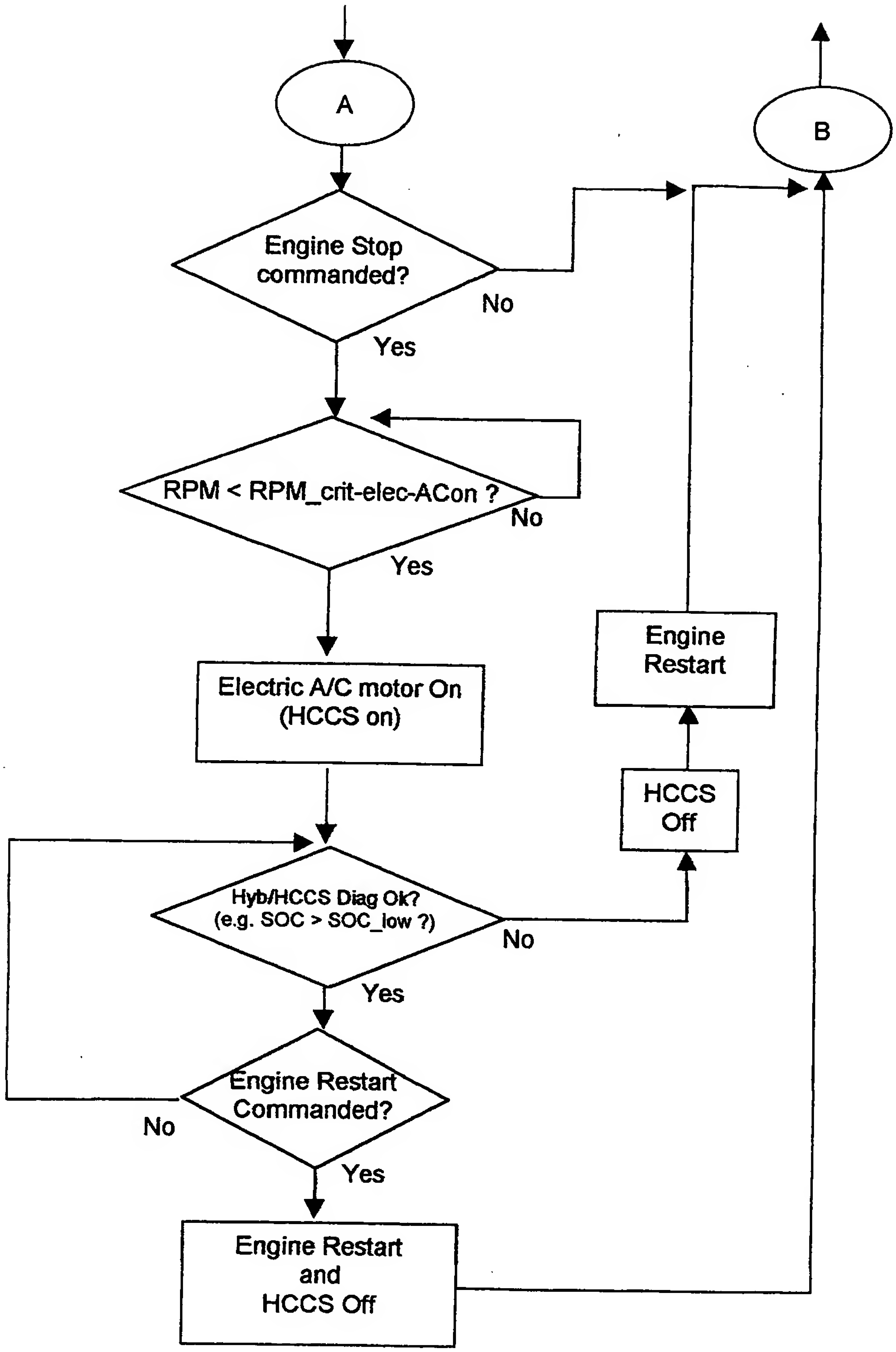

Figure 2b: Simplified schematic of the Hybrid Climate Control System (HCCS); Portion 2 of 2.